Chapter 1.2

The Maryland Coastal Bays ecosystem

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Introduction

The Coastal Bays are estuaries: areas where fresh water mixes with salt water. Due to the flat landscape and sandy soils, rainwater seeps into the ground quickly and groundwater serves as a major pathway of freshwater to the bays. Salinities in the open bays are close to seawater while small portion of the upstream reaches of rivers and creeks remain fresh (Figure 1.2.1). Circulation in the bays is controlled by wind and tides. Tidal exchange with the Ocean is limited to two inlets, one dividing Fenwick and Assateague Islands and the second in Virginia south of Chincoteague Island. The Coastal Bays overall are classified as microtidal. Flushing in the bays (the amount of time it takes to replace all of the water by freshwater and ocean exchange) is very slow. That means that contaminants such as nutrients, sediment and chemicals that enter the bays tend to stay in the bays. Because the systems are shallow and have relatively long water residence times, increased nutrients can have a disproportionate effect relative to the nation's larger and deeper bays such as the Chesapeake Bay, Delaware Bay, Raritan Bay, Narragansett Bay, San Francisco Bay, and Puget Sound.

Influence of the ocean: barrier islands

Barrier islands are rocky, sandy islands and beaches, spits, dunes, eroding headlands, and wetlands located along the Atlantic and gulf coasts. There are 282 barrier islands along the U.S. coastline (Lins 1980). Coastal barriers provide a physical barrier separating bays from ocean yet still allow some mixing with the sea. The beaches and the wildlife resources of these islands attract thousands of tourists and millions of tourist dollars to coastal communities every year. Barrier islands serve two main functions in the Coastal Bays ecosystem. First, they protect the coastlines from severe storm damage. Second, they harbor several habitats that are refuges for wildlife.

Natural barrier island processes help create and maintain habitat and benefit circulation. For example, newly formed inlets often amplify tidal flushing. Many inlets have existed along Fenwick and Assateague Islands over the past 400 years, including the Ocean City Inlet, which was formed during a major storm in 1933 (Figure 1.2.2). During storms, ocean water can wash over the barrier islands, carrying sand from the ocean beaches to the bays. This overwash provides a sediment source for the creation of salt marshes and seagrass beds.

Many marine creatures find shelter in extensive marshlands along the coast. Protected by islands, these salt marsh nurseries add millions of dollars to the economy through commercial and sport fishing opportunities. (Assateague Island National Seashore 2004) Of all the barrier islands between Maine and Mexico, Assateague is one of the last still in a natural state. It's beaches, lagoons, and maritime forests offer a rare solitude not far from a rapidly developing coast.

Rising sea levels and predominant storm winds from the northeast cause a landward migration of the islands. During storms, overwash of the islands by the sea pushes sand to the mainland side in large quantities. Strong winter winds also push sand towards the mainland. Summer hurricanes and winter storms called "Nor' Easters" account for the most dramatic short-term changes to the islands. A large hurricane can overwash large areas of the islands.

These same wind and weather patterns also move sand generally from north to south. At natural inlets sand tends to erode from the north and are transported to the south side. Where man puts hardened structures like jetties or groins in place, the process is interrupted and sand blocked on its normal southerly migration piles up on the north side of a jetty, but is eaten away on the south side by the eddy that is created.

For example, a hurricane opened the Ocean City Inlet in 1933 (the inlet separates Fenwick Island from Assateague Island to the south; Figure 1.2.2). To keep the channel navigable to the mainland, the U.S. Army Corps of Engineers constructed two rock jetties. Although the jetties stabilized the inlet, they altered the normal north-to-south sand transport by the longshore currents. The result is that sand built up behind the north jetty and the sand below the south jetty was quickly eroded. The accelerated erosion (rate of 35 feet per year) has shifted Assateague Island almost one-half mile (0.8 km) inland (USACE 1998). As a result, the Ocean City Inlet is among the best-studied and understood inlets in the world, courtesy of Federal, state and local government tax dollars funding the USACE. Nevertheless, human interventions have permanently altered the barrier island profile (Freudenrich 2004)

Influence of the ocean: hydrodynamics

River input to the Coastal Bays is low and groundwater is an important source of freshwater inflow. Circulation in the bays is mainly controlled by winds and tides. Tidal exchange with the Ocean is limited to two inlets, one dividing Fenwick and Assateague Islands and the second in Virginia south of Chincoteague Island. Tidal range near the Ocean City Inlet is more than 3.4 feet, while it drops to 0.4 feet in the middle of Chincoteague and 1.5 feet in Assawoman Bay (Boynton et al. 1993). Flushing rates have been estimated for the northern segments as follows: Isle of Wight Bay 9.45 days, Assawoman Bay 21.2 days, and St. Martin River 12 days (Lung 1994). The flushing rate for Chincoteague Bay may be as long as 63 days (Pritchard 1969). The actual residence time of any constituent indicator varies from flushing time due to water column kinetics. Processes such as algal uptake and settling of phytoplankton tend to decrease residence time while nutrient recycling increases residence time. Intense benthic – pelagic coupling, which is common in systems such as these, increases the impact of contaminants, such as nutrients, entering the bays.

Nutrient loading

Since point sources (three industrial and four wastewater treatment plants) are heavily regulated in the Coastal Bays, their estimated contribution of nutrients is small (less than five percent of total nutrients) (Boynton et al. 1993). Nutrient inputs to the Coastal Bays are dominated by non-point sources (e.g., surface runoff, groundwater, atmospheric deposition, and shoreline erosion). The amount of nutrients coming from an area is largely dependent on the predominant landuse with agriculture and developed lands generally contributing more nutrient than wetlands and forests. The large variety of non-point sources and pathways makes estimates of relative contribution from different land uses difficult. Current estimates suggest that one-half to two-thirds of nutrients entering the bays come from agriculture sources (Bohlen et al. 1997). Efforts are presently underway to refine these estimates using data collected in the Coastal Bays watershed. The coastal bays are believed to be generally nitrogen limited rather than phosphorus limited (Boynton et al. 1996)

Table 1.2.1 Key physical characteristics of each bay segment (U=unknown).

Bay Segment	Watershed area (km^2)	Average depth (m)	Surface area of bay (km^2)	Watershed: Surface area ratio	Water volume (m^3*10^6)	Watershed: water volume	Flushing rate (days)
Assawoman Bay - MD	24.7	1.20	20.9	1.18	27.0	0.91	21.2
Isle of Wight Bay	51.8	1.22	21.1	2.45	22.85	2.27	9.45
St. Martin River	95.5	0.67	8.40	11.4	5.63	16.96	12
Sinepuxent Bay	26.7	0.67	24.1	1.1	16.5	1.62	U
Newport Bay	113	1.22	15.9	7.1	19.4	5.82	U
Chincoteague Bay (MD)	141	1.22	189	0.75	231	0.61	63
Chincoteague Bay (VA)	174.5	U	188	0.93	143.5	1.22	U
Coastal Bays System MD	452	U	282	1.6	322	1.40	U
Chesapeake	165,759	6.4	18,130	9.1	68,137.	2.4	U

Bay					4		

Anthropogenic nutrient inputs to estuaries are often confounded by significant natural source (e.g., wildlife) inputs and complex delivery systems. Understanding the hydrology and the hydrological functions of a system, therefore, is also vital to assessing nutrient impacts on a system. Determinations must be made on where and how the nutrients are delivered, as well as the time, conditions, and magnitude of the delivery.

Bathymetry and surficial sediment type

Chincoteague Bay, the southernmost of the Coastal Bays, has a drainage area of approximately 141 km^2 and an average depth of 1.22 m (Table 1.2.1). Most of this bay is shallower than one meter, with deeper water in the central channel (7.6 m maximum) pulling the average up. The surface area of the Maryland portion of Chincoteague Bay is 189 km^2. Sediments range from mostly sandy in the eastern part of the bay to silty within the channel to mud along the western shoreline (Boynton et al. 1993; Figure 1.2.3). The average textural composition of the bay bottom sediments is 60% sand, 27% silt and 13% clay (Wells et al. 1997). The average percent organic carbon by dry weight at 0.39 percent (extremely low for an estuarine system). The major source of sedimentation to Chincoteague Bay is storm overwash events, shore erosion and wind erosion from Assateague Island, with stream sedimentation providing relatively little contribution.

Moving north, Newport Bay drains approximately 113 km^2 of land area (Table 1.2.1). The average depth of the bay proper is 1.22 m with a maximum of 1.9 m in a central channel. Newport Bay has a surface area of 15.9 km^2. Sediments are fine-grained, containing mostly silt with little clay (Wells et al. 1996; Figure 1.2.3). Total carbon averaged 1.86 percent for Newport and Sinepuxent Bays combined, with a majority of this contribution from organic sources (Wells et al. 1996). Newport generally has higher carbon contents than Sinepuxent due to more marsh and tributary drainage. Due to the low gradient of Trappe Creek and the other tributaries that constitute the major sediment sources for this Bay, sedimentation rates are relatively low.

Sinepuxent Bay, to the immediate east of Newport Bay, has a drainage of 26.7 km^2 and a surface water area of 24.1 km^2 (Boynton et al.1993; Table 1.2.1). This bay has the shallowest average depth (0.7 m), despite depths around the Ocean City Inlet reaching 7.8 m. The federal government now maintains the inlet and the Ocean City harbor channel. Bottom sediments are fairly course, consisting mostly of sand and, to a lesser degree, silt (Wells et al. 1996; Figure 1.2.3). Sedimentation mainly comes from storm overwash and wind erosion on Assateague Island and occurs at a higher rate here than in any other Bay (Wells et al. 1996) as well as shore erosion. The contribution of fine-grained material from shore erosion is approximately eight times that introduced by streams (Bartberger 1976).

Isle of Wight Bay, directly north of Sinepuxent, has a drainage area of 146 km^2 and a surface water area of 19 km^2 including the St. Martin River. The average depth of this bay is 1.22 m, with a maximum depth of 9.3 m in the Ocean City inlet (maintained by dredging) (Boynton et al. 1993; Table 1.2.1). The federal government now maintains the inlet as well as a channel up the Isle of Wight Bay through periodic dredging, though the inlet throat depth is primarily maintained by scour from tidal currents. Sandier sediment is found along the eastern portions of Isle of Wight Bay, due to overwash and erosion from Fenwick Island. However, since the mid-1970s, development along Fenwick Island has essentially prevented overwash. St. Martin River and Turville Creek sediments contain the least sand and the most clay and have been classified as tidal stream deposits. Major contributors to Isle of Wight sedimentation are Turville Creek and St. Martin River in the west along with sand from Fenwick Island.

The furthest north embayment, Assawoman Bay, drains 24.7 km^2 and has a surface water area of 20.9 km^2 (UMCES 1993). This Bay averages 1 m in depth, with a maximum of 2.5 m in a central channel. The canal (also called the 'ditch') connecting Isle of Wight Bay with Assawoman averages 4.7 m in depth. The average bottom sediment composition for Isle of Wight and Assawoman Bay combined (including the St. Martin River) is 54% sand, 28% silt, and 18% clay (Figure 1.2.3). Total carbon content averages 2.08%, with carbon content reflecting a combination of both terrigenous and planktonic sources (Wells et al. 1994).

Comparison to other Estuaries

Nutrient enrichment in this shallow, poorly flushed coastal bay system is a problem. Progressive eutrophication threatens the long-term health and function of the estuary. Increasing anthropogenic eutrophication and associated environmental and biotic impacts in this and other East Coast estuaries appear to be representative of what is happening in many coastal bay systems worldwide (Figure 1.2.4).

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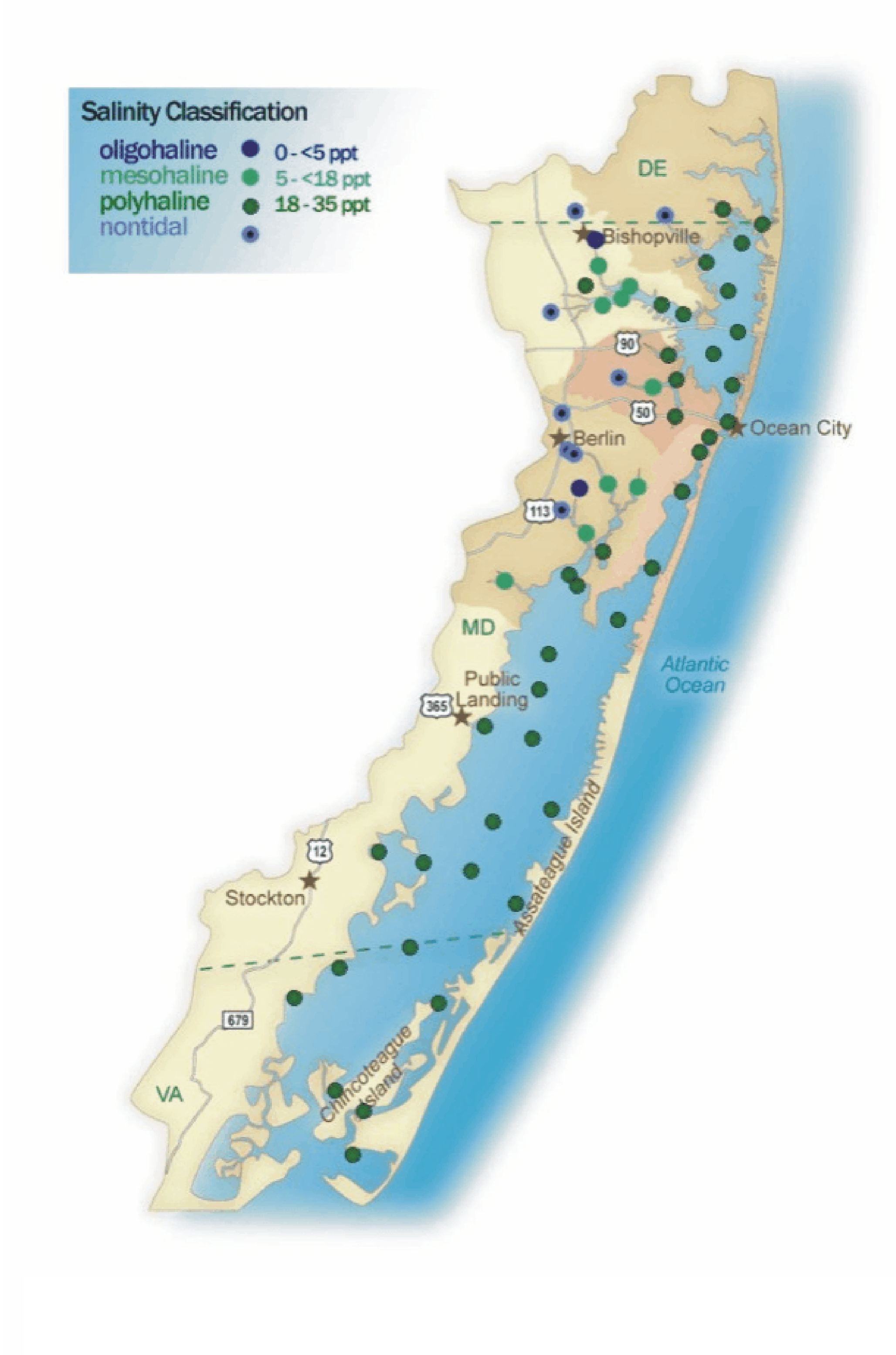

Figure 1.2.1: Salinity classification for water quality sampling stations within the Coastal Bays. Several sampling stations are non-tidal and freshwater.

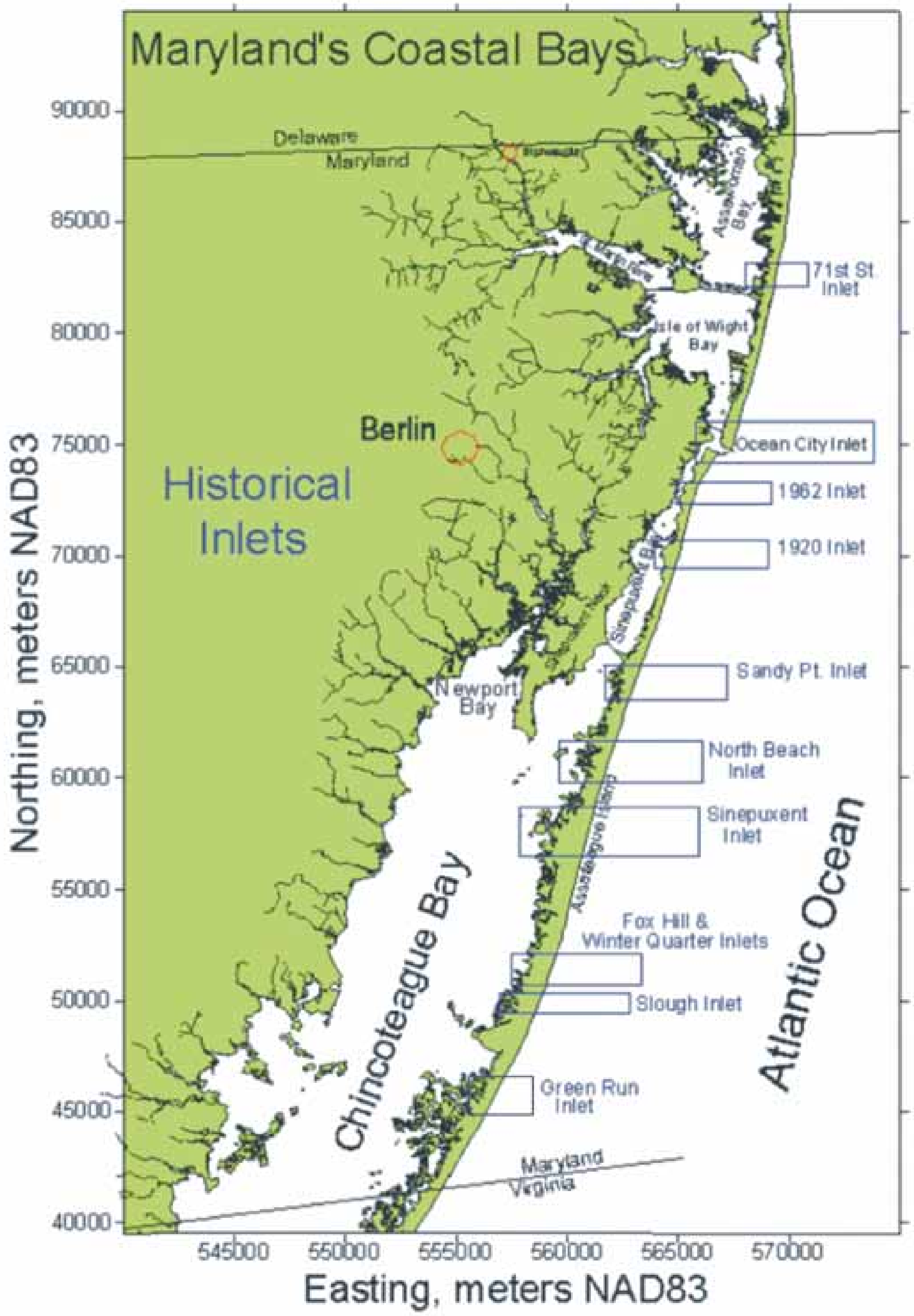

Figure 1.2.2: Historic inlets of the Maryland Coastal Bays, including the current Ocean City Inlet opened in 1933 (see chapter 2.1 for details on time periods for inlets).

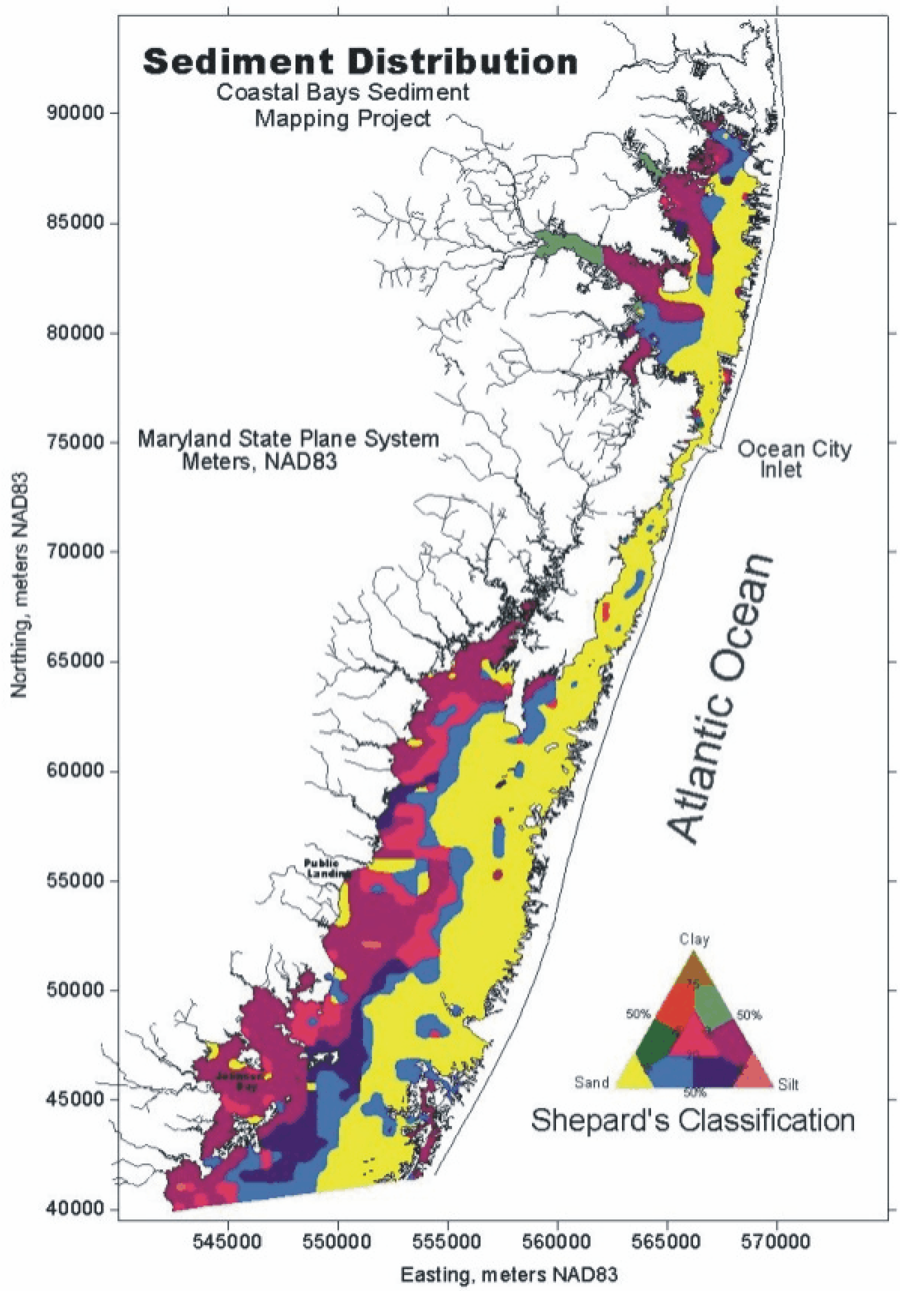

Figure 1.2.3: Sediment distribution in Coastal Bays shallow sediments. The Shepard's classification legend, based on Shepard (1954), shows the relative percentages of sand, silt, and clay in the sediments.

Nutrient Loads to Estuarine Systems

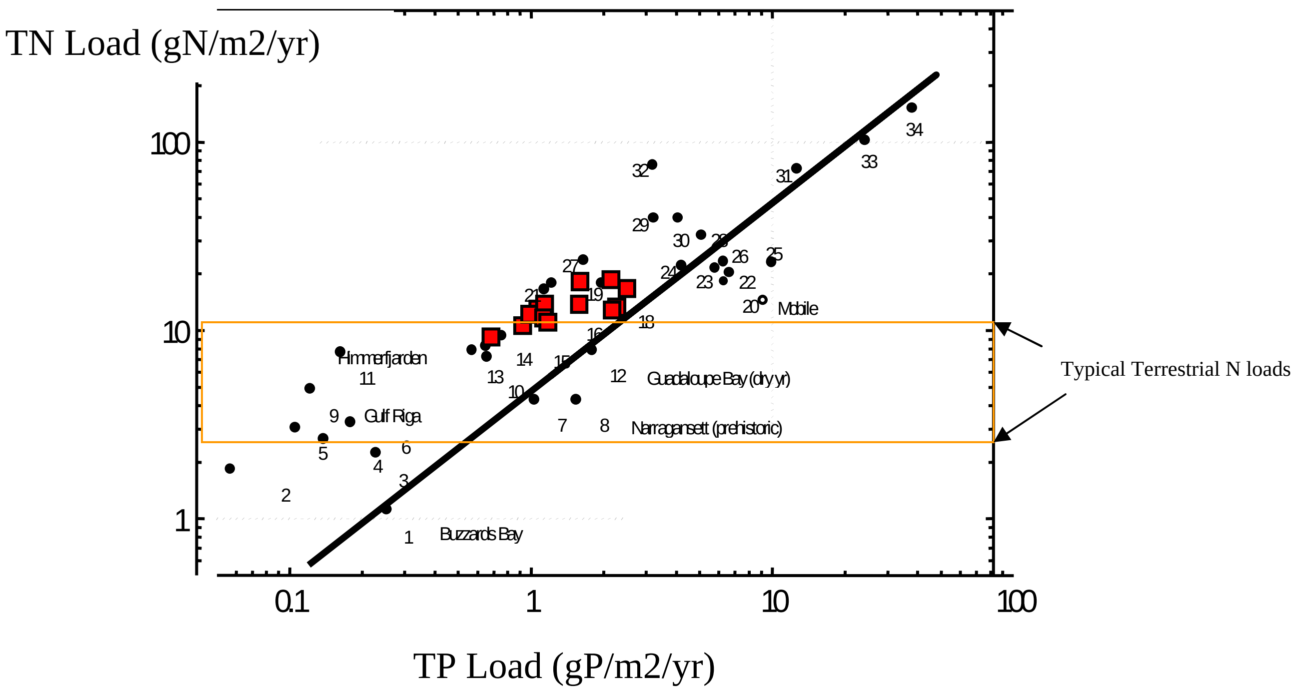

Figure 1.2.4: Scatter diagram showing annual total nitrogen (TN) and total phosphorus (TP) loading rates to a sampling of estuarine and coastal systems. The square symbols represent loads for the Patuxent River estuary for the years 1985-1997. The bold line represents the Redfield Ratio (weight basis). System identification and data sources are as follows: 1 Buzzards Bay, MA (NOAA/EPA 1989); 2 Sinepuxent Bay, MD (Boynton et al. 1992, 1996); 3 and 7 Kaneohe Bay HI pre and post-diversion (Smith et al. 1981); 4 Isle of Wight Bay, MD (Boynton et al. 1992, 1996); 5 Baltic Sea (Nixon et al. 1996); 6 Chincoteague Bay, MD (Boynton et al. 1992, 1996); 8 and 24 prehistoric and current Narragansett Bay, RI (Nixon et al. 1996, Nixon 1997); 9 Gulf of Riga (Yurkovskis et al. 1993); 10 Albemarle Sound, NC (Nixon et al. 1986b); 11 Himmerfjarden, Sweden (Engqvist 1996); 12 and 26 Guadaloupe Bay, TX dry and wet years (Nixon et al. 1996); 13 Buttermilk Bay, MA (Valiela and Costa 1988); 14 Moreton Bay, Australia (Eyre and McKee 2002); 15 Seto Inland Sea, Japan (Nixon et al. 1986b); 16 Taylorville Ck, MD (Boynton et al. 1992, 1996); 18 Newport Bay, MD (Boynton et al. 1992, 1996); 19 N. Adriatic Sea (Degobbis and Gilmartin 1990); 20 Mobile Bay, AL (NOAA/EPA 1989); 21 Chesapeake Bay, MD (Boynton et al. 1995); 22 MERL(1x), Univ RI (Nixon et al. 1986); 23 Delaware Bay, DE (Nixon et al. 1996); 25 N. San Francisco Bay, CA (Hager and Schemel 1992); 27 Potomac River estuary, MD (Boynton et al. 1995); 28 St Martins River, MD (Boynton et al. 1992, 1996); 29 Apalachicola Bay, FL (NOAA/EPA 1989, Mortazavi et al. 2000); 30 Patapsco River, MD (Stammerjohn et al. 1991); 31 Tokyo Bay, Japan (Nixon et al. 1986b); Back River, MD (Boynton et al. 1998); 33 Boston Harbor, MA pre-diversion (Nixon et al. 1996); 34 W. Scheldt, Netherlands (Nixon et al. 1996). Figure courtesy of W. Boynton, University of Maryland.